(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 September 2004 (16.09.2004)

PCT

(10) International Publication Number
WO 2004/079145 A2

(51) International Patent Classification[7]: E21B

(21) International Application Number: PCT/US2003/040349

(22) International Filing Date: 18 December 2003 (18.12.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/451,156 26 February 2003 (26.02.2003) US

(71) Applicant *(for all designated States except US)*: **EXXON-MOBIL UPSTREAM RESEARCH COMPANY** [US/US]; P.O Box 2189, Houston, TX 77252-2189 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **BARRY, Michael, D.** [US/US]; 251 N. Maple Glade Circle, The Woodlands, TX 77382 (US). **BLACKLOCK, Jon** [US/US]; 1011 Portrush Court, Katy, TX 77494 (US). **CHANDLER, Karen** [US/US]; 39 Orchard Falls Drive, Sugar Land, TX 77479 (US). **DALE, Bruce, A.** [US/US]; 7122 Hidden Trails Court, Sugar Land, TX 77479 (US). **DI PIPPO, Matt, M.** [US/US]; 2828 Hayes Road #733, Houston, TX 77082 (US). **HECKER, Michael, T.** [US/US]; 16211 Castle Grove Court, Tomball, TX 77377 (US). **MARTIN, Ben, L., III** [US/US]; 29500 Perdido Beach Blvd. #401, Orange Beach, AL 36561 (US). **MARTIN, Thomas, B., Jr.** [US/US]; 135 S. Grapevine Circle, The Woodlands, TX 77382 (US). **ROSENBAUM, Darren, F.** [US/US]; 8019 Meadow Pond Drive, Missouri City, TX 77459 (US). **SHUCHART, Chris, E.** [US/US]; 1519 Timber Creek Drive, Missouri City, TX 77459 (US).

(74) Agents: **KATZ, Gary, P.** et al.; ExxonMobil Upstream Research Company, P.O. Box 2189, Houston TX 77252-2189 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*

[Continued on next page]

(54) Title: METHOD FOR DRILLING AND COMPLETING WELLS

(57) **Abstract:** A method for drilling and completing a gravel packed well is disclosed. The method comprises drilling a wellbore with a drilling fluid, conditioning the drilling fluid, running the gravel packing assembly tools to depth in the wellbore with the conditioned drilling-fluid, and gravel packing a wellbore interval with a completion-fluid. The completion fluid may be the same as the drilling-fluid. This method may be combined with alternate-path sand screen technology to ensure proper distribution of the gravel pack.

WO 2004/079145 A2

- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*
- *of inventorship (Rule 4.17(iv)) for US only*

Published:

- *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD FOR DRILLING AND COMPLETING WELLS

FIELD OF THE INVENTION

This invention generally relates to wellbores used for production of formation fluids. More particularly, this invention relates to well completion providing the ability to utilize one fluid for drilling the wellbore, running the gravel packing assembly and sand control screens, and then displacing and gravel packing the completion interval with the same or another fluid.

BACKGROUND

The proper fluids for drilling, gravel packing and sand screens installation are essential for well completion success. Careful planning, well preparation and completion execution are required to increase completion productivity and longevity. Historically, a minimum of three fluids has been used to drill and complete gravel packed wells. The first fluid is a solids-laden drilling-fluid used to drill the completion interval. The second fluid is a solids-free completion-fluid used to displace the solids-laden drilling-fluid and to run sand-exclusion equipment and gravel packing tools in a generally solids-free environment. The third fluid is a carrier fluid for the gravel during gravel packing of the completion interval.

In producing hydrocarbons a wellbore is drilled through a subterranean reservoir. Drilling practices can affect a gravel pack and sand screen the same way they can affect conventionally perforated wells. The well should be drilled to maintain wellbore stability, and drilling fluids should be used that will not damage the formation.

The drilling fluid typically contains weighting solids, viscosifying solids, and drilled solids at varying concentrations. Drilling fluid filtrates should be compatible with completion fluids and should not interfere with the completion operations. Preferably, the drilling fluid selected should be dense enough to result in a well that is

slightly overbalanced, should have low fluid loss and should be compatible with the clays in the productive formation.

The proper preparation of a well for gravel packing can be the key to completion success. Cleanliness is one of the most important considerations in the preparation of gravel packs. The presence of any particulate materials can result in a damaged completion. Currently tanks are often dedicated to gravel pack use to avoid repeated cleaning operations for drilling mud removal.

Completion fluids are used to displace the solids-laden drilling fluid and to run sand-exclusion equipment and gravel packing tools in a generally solids-free environment. Completion fluids can be oil- or water-based fluids. The water-based fluids are usually considered to be more flexible. Their densities, viscosities, and formation compatabilities are more easily controlled than those of oil-based fluids. Therefore, water-based fluids are most commonly utilized.

Regardless of the source of the completion fluid, the fluid should contain minimum particulate material and its chemistry must be compatible with the rock formation and connate water. Fresh water may cause clays to swell or disperse, while the presence of some ions may cause precipitation when in contact with formation water. The most common sources of completion fluids are field or produced brine, seawater, bay water or fresh water. The density of the completion fluids is often controlled with soluble salts.

Gravel placement involves those operations required to transport gravel from the surface to the completion interval to form a downhole filter that will permit the flow of fluids into the well but will prevent the entry of formation sands. Preferably, the gravel placement provides a uniform pack with a porosity of thirty-nine percent or less.

The gravel placement requires fluid to transport the gravel slurry to the completion interval. Oil- and water-based fluids and foams are commonly used as the gravel placement fluid. Clean fluids are essential for gravel placement. Depending on well pressures, high-density, solids-free soluble salt solutions may be required to

maintain well control. In addition, the gravel placement fluids can be viscified by adding polymers.

Poor distribution of the gravel slurry is often caused when carrier fluid from the slurry is lost prematurely into the more permeable portions of the formation and/or into the screen, itself, thereby causing "sand bridge(s)" to form in the well annulus around the screen. These sand bridges effectively block further flow of the gravel slurry through the well annulus thereby preventing delivery of gravel to all levels within the completion interval.

To alleviate poor gravel distribution, "alternate-path" well tools or technology have been proposed and are now in use which provide for uniform distribution of gravel throughout the entire completion interval notwithstanding sand bridges formation before completion of gravel distribution. Such devices typically include perforated shunts or by-pass conduits which extend along the length of the device and which are adapted to receive the gravel slurry as it enters the well annulus around the device. If a sand bridge forms before the operation is complete, the gravel slurry can still be delivered through the perforated shunt tubes (such as, "alternate-paths") to the different levels within the annulus, both above and/or below the bridge. U.S. Patent Nos. 4,945,994 and 6,220,345 provides descriptions of typical alternate-path well screens and how they operate.

To summarize, the current method used to install open-hole gravel packs typically involves drilling the completion interval with water- or oil-based drilling fluid, displacing the fluid in the open-hole to a solids-free completion fluid (typically brine), running the gravel pack assembly and sand screens to depth in the solids-free completion fluid, and gravel packing the interval with a water-based carrier fluid. A common limitation of this method involves the inability to run the gravel pack assembly and sand screens to depth due to wellbore instability (collapse) caused by incompatibility between the water-based completion fluid (brine) and the formation. This method is inefficient since at least three fluids are required (drilling fluid, completion fluid, and gravel carrier fluid).

A frequent modification to the method described above involves placing a pre-drilled liner in the completion interval prior to displacing the open-hole to completion fluid and running the gravel pack assembly and sand screens (Murray, G., Morton, K., Blattel, S., Davidson, E., MacMillan, N., Roberts, J., SPE 73727, February 20-21, 2002. Development of the Alba Field - Evolution of Completion Practices, Part 2 Open Hole Completions; Successful Outcome - Drilling with SBM and Gravel Packing with Water Based Carrier Fluid and Gilchrist, J.M., Sutton, Jr., L.W., Elliot, F.J., SPE 48976, September 27-30, 1988. Advancing Horizontal Well Sand Control Technology: An OHGP Using Synthetic OBM.). The pre-drilled liner mitigates wellbore collapse and provides a conduit for running the gravel pack assembly and sand screens. While the pre-drilled liner improves the ability to run the gravel pack assembly and sand screens to depth, it provides an additional resistance to flow and may have a negative impact on productivity.

The current practice of using separate fluids for drilling, displacing the solids-laden drilling fluid and running sand-exclusion equipment and gravel packing tool, and gravel placement is both costly and time-consuming. Accordingly, there is a need to reduce operational complexity and time by simplifying the fluid system and eliminating the need for the pre-drilled liner. This invention satisfies that need.

SUMMARY

In an embodiment, the method comprises drilling a wellbore with a drilling fluid, conditioning the drilling fluid, running the gravel packing assembly tools to depth in a wellbore with the conditioned drilling fluid, and gravel packing an interval of the wellbore using a carrier fluid. The carrier-fluid may be the same as the drilling fluid. This method may be combined with alternate-path sand screen technology to ensure proper distribution of the gravel pack

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow chart of an embodiment of the invention;

Figure 2 is an illustration of wellbore with gravel packing using a two- fluid system illustrating the installation of an alternate-path sand screen in an oil-based conditioned fluid;

Figure 3 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the installation of a GP packer and the introduction of the neat gravel pack with the crossover tool in the reverse position;

Figure 4 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the displacement of the gravel pack with the crossover tool in the gravel pack position;

Figure 5 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the reverse position of the crossover tool after the gravel packing and the reverse-out of the open-hole volume and the remaining neat gravel pack fluid with the conditioned oil-based fluid;

Figure 6 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the location of the viscous spacer, neat gravel pack fluid and the gravel pack slurry in the drillpipe with the crossover tool in the reverse position and placement of the gravel pack fluid in the annulus;

Figure 7 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the shift of the crossover tool from the reverse position to the gravel pack position and the removal of returns through the annulus;

Figure 8 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the continued displacement of the oil-based fluid out of the annulus and the diversion of a gravel pack slurry around a sand bridge;

Figure 9 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the displacement of the gravel pack slurry with a completion- fluid until screen-out occurs;

Figure 10 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating the reverse position of the crossover tool with completion fluid pumped into the annulus and a reverse-out of the excess sand and gravel pack fluid;

Figure 11 is an illustration of wellbore with a gravel packing using a two- fluid system illustrating a fully displaced well to completion fluid and the gravel pack assembly pulled out of the wellbore.

DETAILED DESCRIPTION

The invention described herein provides a method for installing an open-hole gravel pack completion. The installation process involves drilling the completion interval with drilling fluid, conditioning the drilling fluid, running the gravel packing assembly and sand control screens to depth in the conditioned drilling fluid, then displacing and gravel packing the completion interval with the same or another fluid.

This new method for installing open-hole gravel pack completions addresses problems that have been experienced while attempting to run sand screens to depth in the wellbore prior to gravel packing. In addition, benefits of the new procedure include reduced completion time due to simplified operational procedures and potential elimination of a slotted liner.

As shown in figure 1, the method has four basic steps. First, a well is drilled in a interval through a subterranean formation with a drilling fluid **1**. Second, the drilling fluid is conditioned **2**. Third, the gravel pack assembly tools are run to depth in the wellbore with the conditioned fluid **3**. Fourth, an interval of the wellbore is gravel packed with a completion fluid **4**. The completion fluid can be the same as the conditioned fluid or a separate fluid. If the wellbore does not need to be gravel packed a screen can be run to depth in the wellbore with the conditioned fluid with the fourth step no longer necessary.

The completion interval is drilled with either water-based or oil-based drilling fluid. After drilling the completion interval, the drilling fluid is circulated through the wellbore and filtered (or conditioned) using equipment on the rig floor. The drilling fluid contains particles (such as, drill cuttings) that may plug the openings (or slots) in the sand screen and potentially plug the gravel pack if not sufficiently removed. Therefore, the drilling fluid is conditioned (or filtered) before running the sand screens

to preferably remove solid particles larger than approximately one-third the slot opening size and/or one-sixth the diameter of the gravel pack particle size.

The one-third slot size is based on the general rule of thumb for size of spherical particles required to bridge a given slot size. The one-sixth diameter of the gravel pack particle size is based on the general rule of thumb for the required size of pore throats in a pack of spherical particles at a given diameter to avoid plugging. For example, typical wire-wrapped sand screens have 8.5 gauge slots (approximately 215 microns) and 30/50 proppant (approximately 425 microns) may be used for the gravel packs. The drilling fluid can be conditioned over 310 mesh shaker screens (approximately 50 microns) on the drilling rig, which should sufficiently filter-out the oversized particles.

Also, during field operations, a screen tester apparatus may be utilized to check samples of the conditioned fluid to verify whether it freely passes through a screen sample with a specified slot size. Typically, the recommended slot size is 3 to 4 gauge sizes less than nominal screen slots. Once the fluid conditioning process is adequately verified using the screen tester apparatus, the gravel pack assembly and sand screens can be run to depth in the wellbore.

Running sand screens in conditioned-fluid for stand-alone screen completions is a frequent operational practice for persons skilled in the art. For example, this practice is often conducted in the North Sea where gravel packing is not necessary due to the high permeability formations that have large sand grains with uniform size distributions. For open-hole completions that must be gravel packed due to heterogeneous formation with non-uniform grain size distributions, prior to this new method sand screens were not run in conditioned fluid

After the gravel pack assembly and sand screens are run to depth, the open-hole interval fluid is typically displaced with a volume of neat fluid. Neat fluid is gravel carrier fluid not laden with gravel pack proppants. The displacement removes conditioned drilling fluid and drill cuttings that remain in the open-hole. The displacement fluid is circulated in a direction that does not direct solids-laden fluid through the screen in an effort to avoid screen plugging. For example, the fluid can be

circulated down the annulus, through the crossover to the washpipe, down the washpipe of the screen assembly, and out the screen. Previously, open-hole gravel pack installation methods required the completion of the displacement operation before installing sand screens because previous methods assumed sand screens should be run in solids-free fluid.

After the open-hole interval is displaced, the completion interval is gravel packed using standard operational procedures. The pump rate for the gravel pack operation should be slower than the displacement rate to avoid screen plugging.

In addition, after the gravel pack assembly has been run and prior to the gravel packing operation, several gravel pack service tool manipulations must be performed. The new method requires that the manipulations be performed in solids-laden fluid which was not done in previous methods (gravel pack assembly previously run in solids-free fluid).

In another embodiment, the invention involves drilling a completion interval in a wellbore with an oil-based drilling fluid and gravel packing an interval of the wellbore with a water-based carrier fluid using alternate-path technology. Compared to water-based fluids, oil-based fluid filter cakes have lower lift-off pressures that can be problematic for installing a complete gravel pack. Filter cake is a concentrated layer of solids from the drilling fluid that forms on the borehole wall opposite a permeable formation. Loss of the filtercake during gravel packing may result in the formation of a bridge. As described previously in the background section, alternate path allows transport of sand beyond the bridge. As a result, alternate-path technology is desirable for wells that are to be gravel packed and are drilled with oil-based fluid.

The water-based gravel pack carrier fluid should have favorable rheology for effectively displacing the conditioned fluid and favorable rheology and sand carrying capacity for gravel packing using alternate path technology. Examples of the water-based carrier fluid include but are not limited to a fluid viscosified with HEC polymer, xanthan polymer, visco-elastic surfactant (VES) or combinations thereof. Persons skilled in the art will recognize other carrier fluids that may be chosen because of their favorable properties.

In another embodiment, the gravel pack carrier fluid is oil-based. The method using the oil-based carrier fluid would be the same as described above with the water-based carrier fluid.

Example

The invention was developed as a result of operational difficulties experienced while attempting to run the gravel pack assembly in a wellbore. The planned procedure for the wellbore was to drill the completion interval, displace to solids-free brine, run the gravel pack assembly and screens, then gravel pack the completion interval using water-based carrier fluid. However, after displacing the open-hole completion interval to completion brine, the gravel pack assembly and sand screens could not be run to depth after several attempts due to wellbore stability problems. Unsuccessful attempts were also made to run a pre-drilled liner. The wellbore was suspended and operations were moved to a nearby wellbore. After the experience at the first failed wellbore, a new completion procedure (the present inventive method) was developed and utilized for the nearby wellbore and subsequent wellbores. The new completion procedure has been successfully employed for multiple wells. Well tests have indicated that the new method provides an efficient, low-skin completion.

Figures 2 through 11 illustrate the two-fluid system well completion using an alternate path well screen in a field test wherein like elements of figures 2 through 11 have been given like numerals. First a well is drilled using a drilling fluid with techniques known to persons skilled in the art. Next, a well screen is installed in a wellbore filled with conditioned non-aqueous fluid (NAF). Figure 2 is an illustration of a screen **27** with alternate path technology **21** inside a wellbore **23**, which is part of the gravel pack assembly. The gravel pack assembly consists of a wellscreen **27**, alternate path technology **21**, a GP Packer **29**, and a crossover tool **35** with fluid ports **26** connecting the drillpipe **28**, washpipe **41** and the annulus of the wellbore **23** above and below the GP Packer **29**. This wellbore **23** consists of a cased section **22** and a lower open-hole section **24**. Typically, the gravel pack assembly is lowered and set in the wellbore **23** on a drillpipe **28**. The NAF **25** in the wellbore **23** had previously been

conditioned over 310 mesh shakers (not shown) and passed through a screen sample (not shown) 2-3 gauge sizes smaller than the gravel pack screen **27** in the wellbore **23**.

As illustrated in figure 3, the GP packer **29** is set in the wellbore **23** directly above the interval to be gravel packed. The GP Packer seals the interval from the rest of the wellbore **23**. After the GP Packer **29** is set, the crossover tool **35** is shifted into the reverse position and neat gravel pack fluid **33** is pumped down the drillpipe **28** and placed into the annulus between the casing **22** and the drillpipe **28**, displacing the conditioned oil-based fluid **25**. The arrows **36** indicate the flowpath of the fluid.

Next, as illustrated in figure 4, the crossover tool **35** is shifted into the circulating gravel pack position. Conditioned NAF **25** is then pumped down the annulus between the casing **22** and the drillpipe **28** pushing the neat gravel pack fluid **33** through the washpipe **41**, out the screens **27**, sweeping the open-hole annulus **45** between the alternate path tools **21** and the open-hole **24** and through the crossover tool **35** into the drillpipe **28**. The arrows **46** indicate the flowpath through the open-hole **24** and the alternate path tools **21** in the wellbore **23**.

As illustrated in figure 5, once the open-hole annulus **45** between the alternate path tools **21** and the open-hole 24 has been swept with neat gravel pack fluid **33**, the crossover tool **35** is shifted to the reverse position. Conditioned NAF **25** is pumped down the annulus between the casing **22** and the drillpipe **28** causing a reverse-out by pushing NAF **25** and dirty gravel pack fluid **51** out of the drillpipe **28**.

Next, as illustrated in figure 6, while the crossover tool **35** remains in the reverse position, a viscous spacer **61**, neat gravel pack fluid **33** and gravel pack slurry **63** are pumped down the drillpipe **28**. The arrows **66** indicate direction of fluid flow of fluid while the crossover tool **35** is in the reverse position. After the viscous spacer **61** and 50% of the neat gravel pack fluid **33** are in the annulus between the casing **22** and drillpipe **28**, the crossover tool **35** is shifted into the circulating gravel pack position.

Next, as illustrated in figure 7, the appropriate amount of gravel pack slurry **63** to pack the open-hole annulus **45** between the alternate path tools **21** and the open-hole **24** is pumped down the drillpipe **28**, with the crossover tool **20** in the circulating

gravel pack position. The arrows **77** indicate direction of fluid flow of fluid while the crossover tool **35** is in the gravel pack position. The pumping of the gravel pack slurry **63** down the drillpipe **28**, forces the neat gravel pack fluid **33** through the screens **27**, up the washpipe **41** and into the annulus between the casing **22** and the drillpipe **28**. Conditioned NAF **25** returns are forced through the annulus between the casing **22** and the drillpipe **28** as the neat gravel pack fluid **33** enters the annulus between the casing **22** and the drillpipe **28**.

As illustrated in figure 8, the gravel pack slurry **63** is then pumped down the drillpipe **31** by introducing a completion fluid **101** into the drillpipe **28**. The gravel pack slurry **63** displaces the conditioned NAF (not shown) out of the annulus between the casing **22** and the drillpipe **28**. Next, gravel is deposited in the open-hole annulus **45** between the alternate path tools **21** and the open-hole **24**. If a sand bridge **81** forms as shown in Figure 8, then gravel pack slurry **63** is diverted into the shunt tubes of the alternate-path tool **21** and resumes packing the open-hole annulus **45** between the alternate path tools **21** and the open-hole **24** and below the sand bridge **81**. The arrows **86** illustrate the fluid flow of the gravel pack slurry down the drillpipe **28** through the crossover tool **35** into the annulus of the wellbore below the GP Packer **29** through the alternate-path tool **21** to the open-hole annulus **45** between the alternate path tools **21** and the open-hole **24** and below the sand screen **81**. The arrows **86** further indicate the fluid flow of the neat gravel pack fluid **33** up the washpipe **41** through the crossover tool **35** in the annulus between the casing **22** and the drillpipe **28**.

Figure 9 illustrates a wellbore **23** immediately after fully packing the annulus between the screen **27** and casing **22** below the GP packer **29**. Once the screen **27** is covered with sand **91** and the shunt tubes of the alternate path tool **21** are full of sand, the drillpipe **28** fluid pressure increases, which is known as a screenout. The arrows **96** illustrate the fluid flowpath as the gravel pack slurry **63** and the neat gravel pack fluid **33** is displaced by completion fluid **101**.

As illustrated in figure 10, after a screenout occurs, the crossover tool **35** is shifted to the reverse position. A viscous spacer **61** is pumped down the annulus

between the drillpipe **28** and the casing **22** followed by completion fluid **101** down the annulus between the casing **22** and the drillpipe **28**. Thus, creating a reverse-out by pushing the remaining gravel pack slurry **63** and neat gravel pack fluid **33** out of the drillpipe **39**. Finally, as shown in figure 11, the fluid in the annulus between the casing **22** and the drillpipe **28** has been displaced with completion brine **101**, and the crossover tool (not shown) and drillpipe (not shown) is pulled out of the wellbore **23** leaving behind a fully-packed well interval below the GP Packer **29**.

Laboratory testing was conducted to qualify the inventive method described above before the method was field-tested. Laboratory testing indicated that the solids contamination of a gravel pack (potential result of an inefficient displacement of solids laden drilling fluid) does not impair the pack permeability. The test involved mixing a volume of gravel with a volume of drilling fluid and packing the mixture into a cylindrical flow apparatus. The drilling fluid was displaced from the gravel by flowing another fluid through the pack. Measurements of the permeability of the initial gravel pack not previously mixed with solids-laden drilling fluid and measurements of the gravel pack after the drilling fluid had been displaced from the pack were similar indicating negligible potential for impairment. In addition, to the laboratory test, the successful field trial, described above verified the feasibility of the procedures described above. The procedures include fluid conditioning procedures, field testing apparatus procedures to monitor the conditioning process and the manipulation procedures (reverse and circulating positions) of gravel pack service tools described above. Furthermore, the fluid displacement efficiencies of using solids-laden drilling fluid and gravel carrier fluids with sand screens in the wellbore were also verified.

CLAIMS

What is claimed is:

1. A method for drilling and completing a gravel packed well comprising:

drilling a wellbore through a subterranean formation with a drilling fluid;

conditioning the drilling fluid;

running the gravel packing assembly tools and sand screens to depth in a wellbore with the conditioned drilling fluid;

gravel packing an interval of the wellbore with a completion-fluid.

2. The method of claim 1 wherein the completion fluid is the drilling fluid.

3. The method of claim 1 wherein the drilling fluid is a solids-laden oil-based fluid.

4. The method of claim 1 wherein the drilling fluid is a solids-laden water-based fluid.

5. The method of claim 1 wherein the conditioning of the drilling fluid removes solid particles larger than approximately one-third the slot opening size of any sand screen utilized in the wellbore.

6. The method of claim 1 wherein the conditioning of the drilling fluid removes solids particles larger than one-sixth the diameter of the gravel pack particle size.

7. The method of claim 1 wherein the sand screens includes alternate-path technology.

8. The method of claim 1 wherein the carrier fluid is chosen from the group consisting of fluid viscosified with HEC polymer, xanthan polymer, visco-elastic surfactant (VES), and any combination thereof.

9. The method of claim 1 wherein the carrier fluid is chosen to have favorable rheology for effectively displacing the conditioned fluid.

10. The method of claim 8 wherein the carrier fluid is chosen to have favorable rheology and sand carrying capacity for gravel packing using alternate path technology.

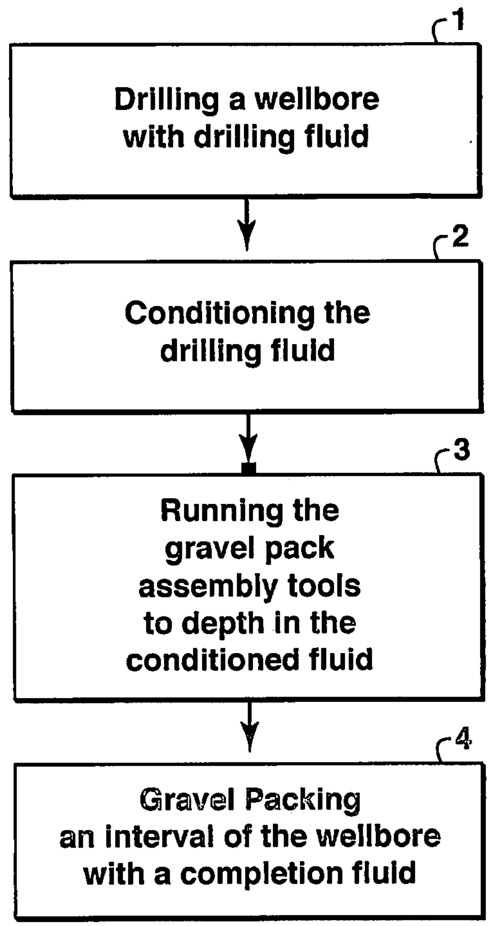
1
Drilling a wellbore with drilling fluid
2
Conditioning the drilling fluid
3
Running the gravel pack assembly tools to depth in the conditioned fluid
4
Gravel Packing an interval of the wellbore with a completion fluid

FIG. 1

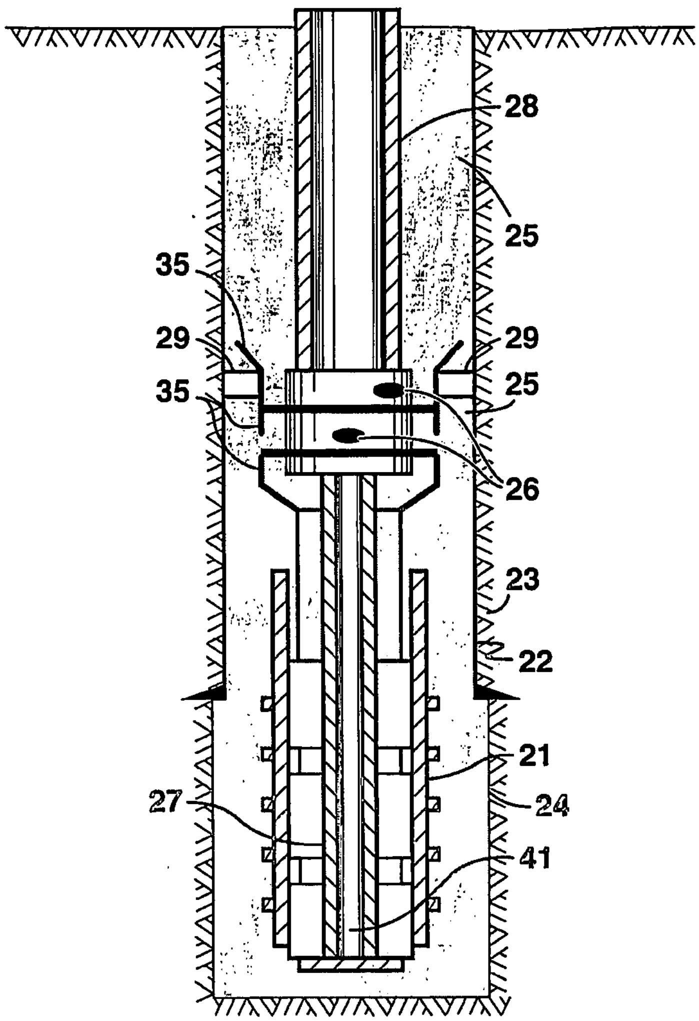

FIG. 2

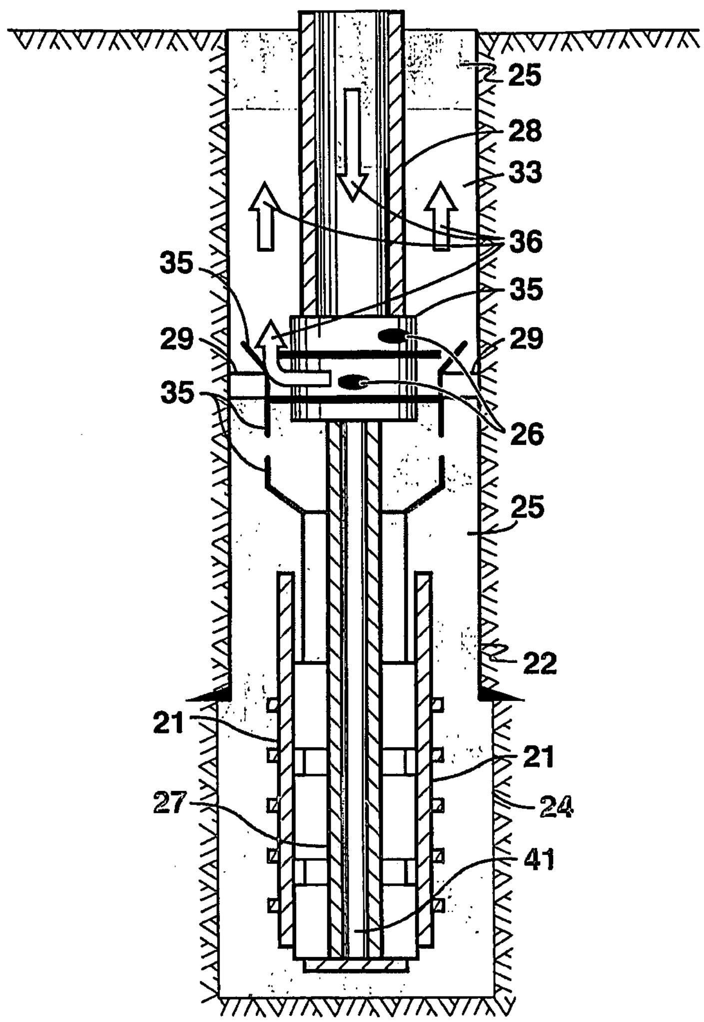

FIG. 3

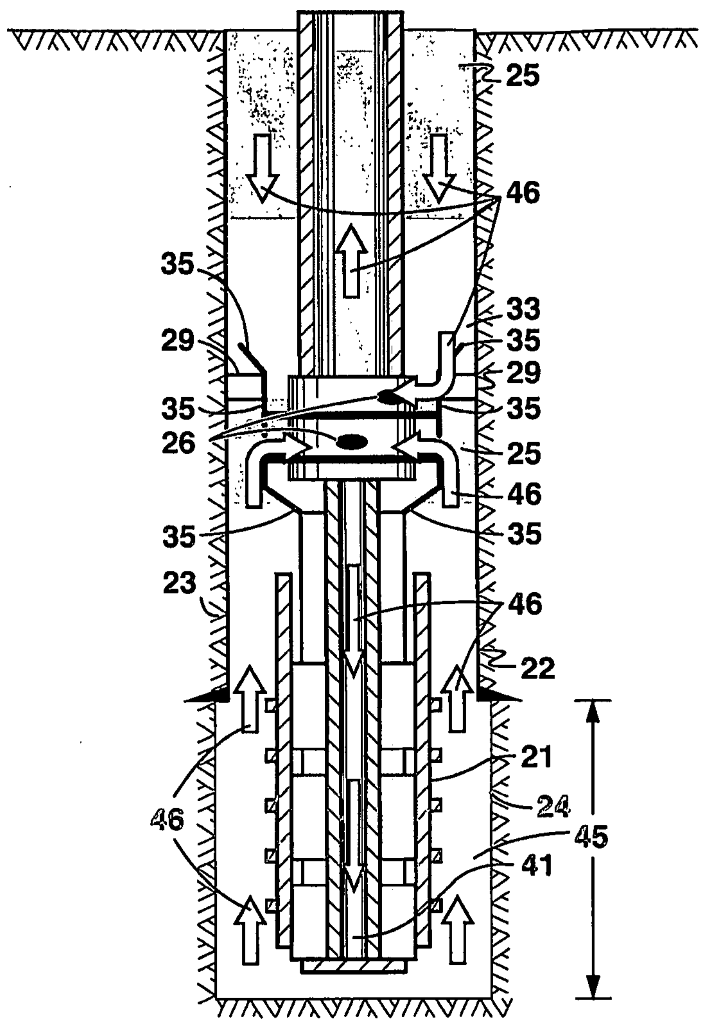

FIG. 4

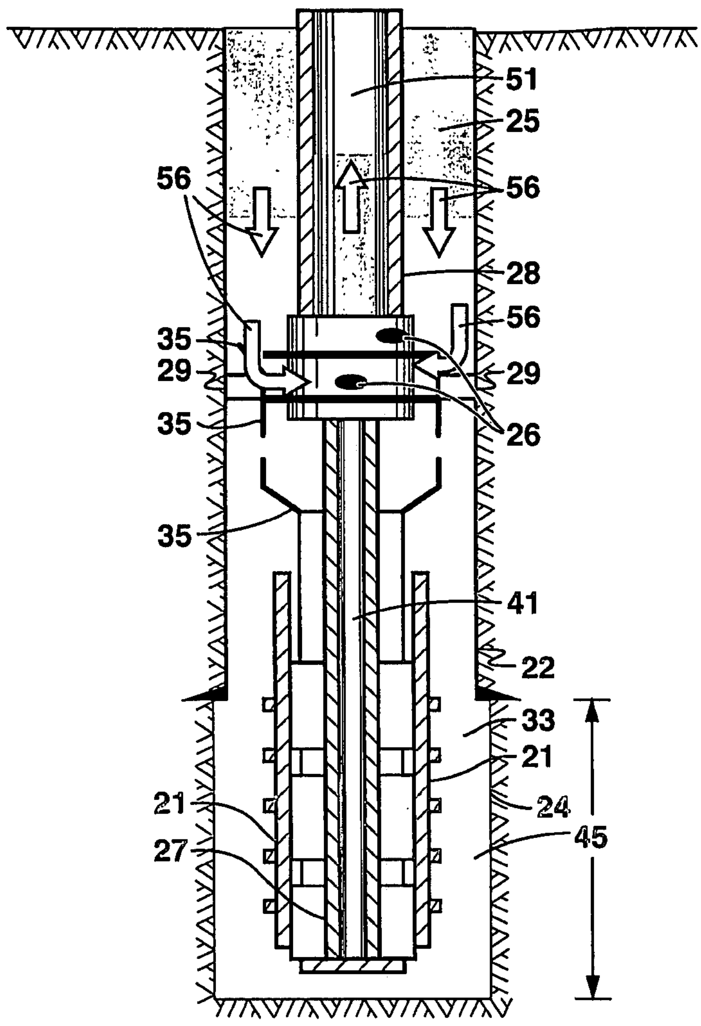

FIG. 5

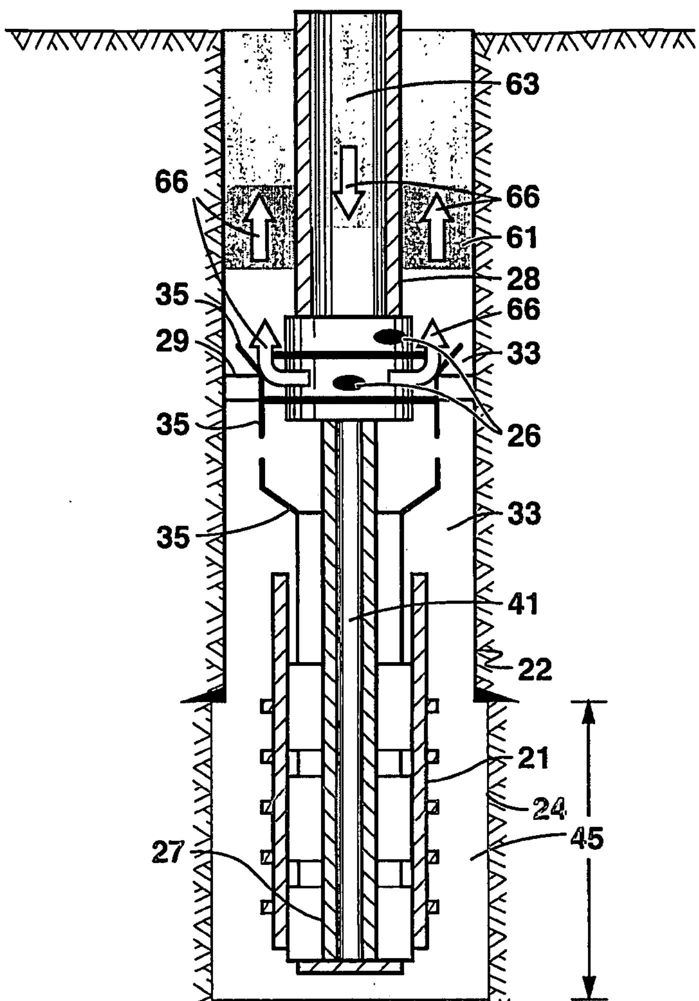

FIG. 6

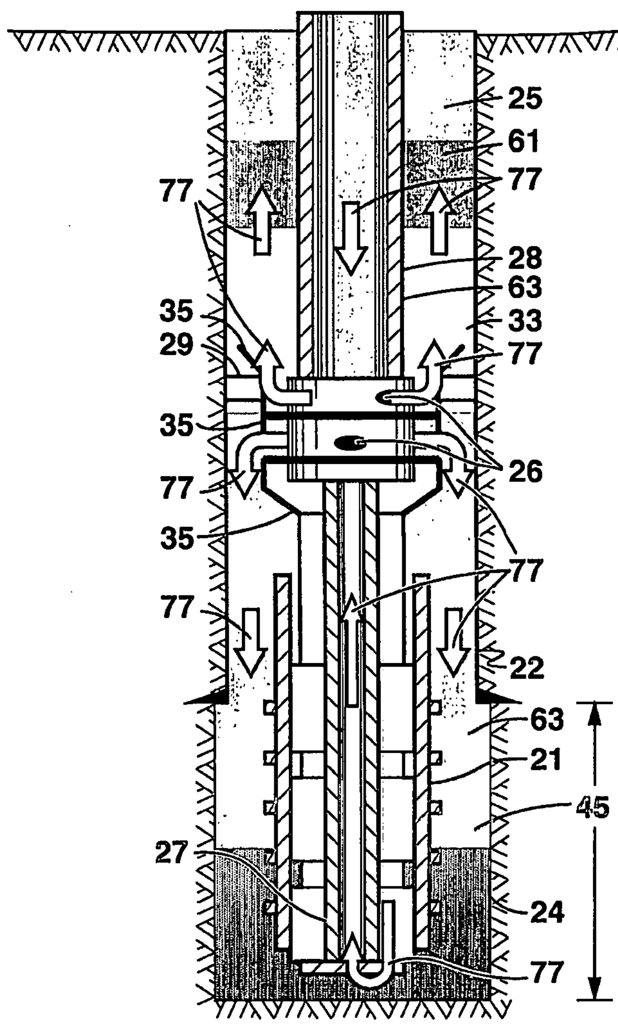

FIG. 7

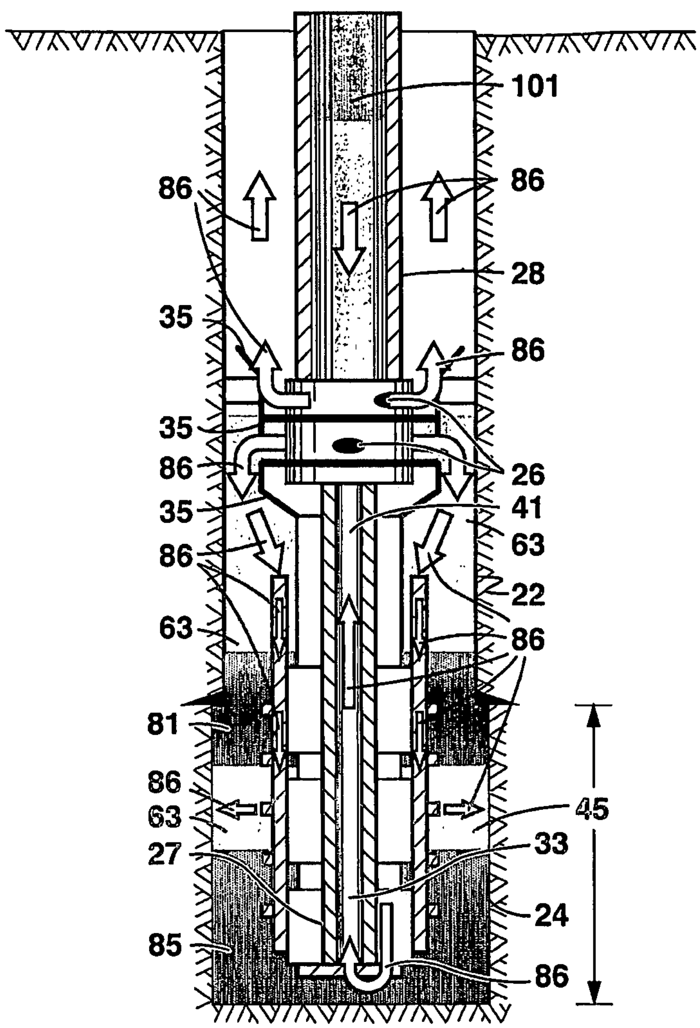
101
86
86
28
35
86
35
26
86
35
41
63
86
22
63
86
81
86
45
63
33
27
24
85
86

FIG. 8

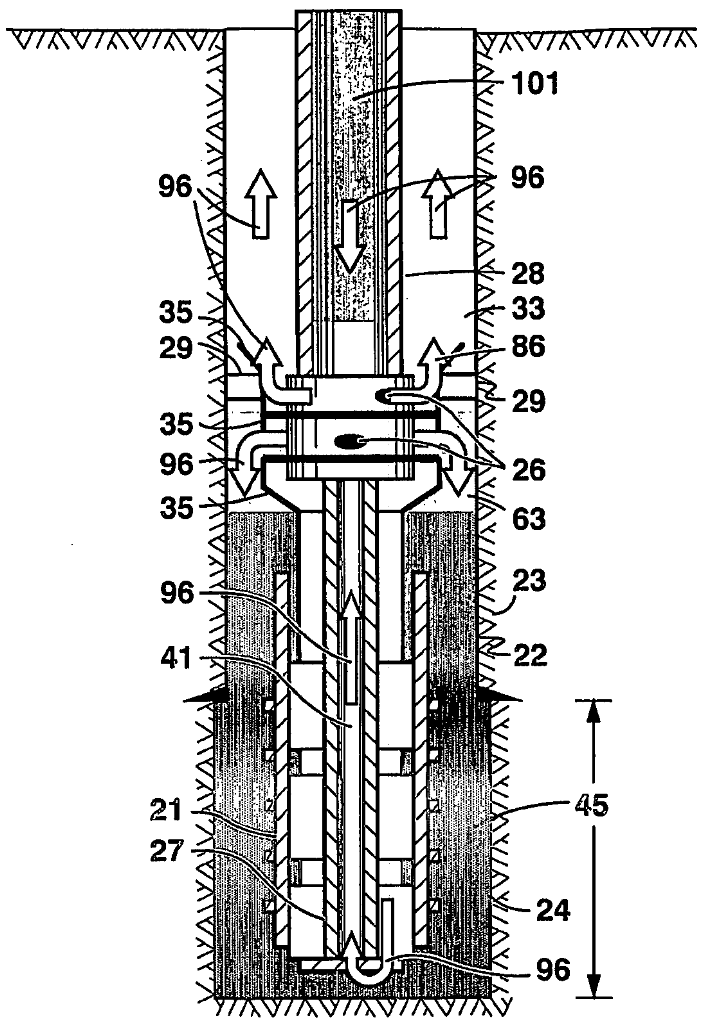

FIG. 9

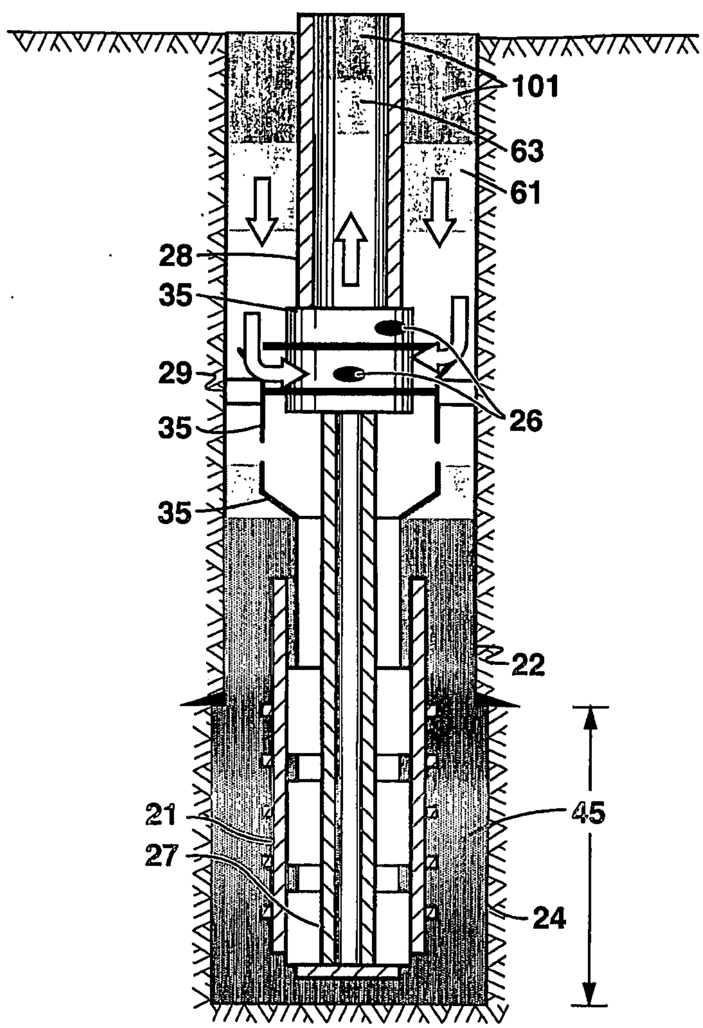

FIG. 10

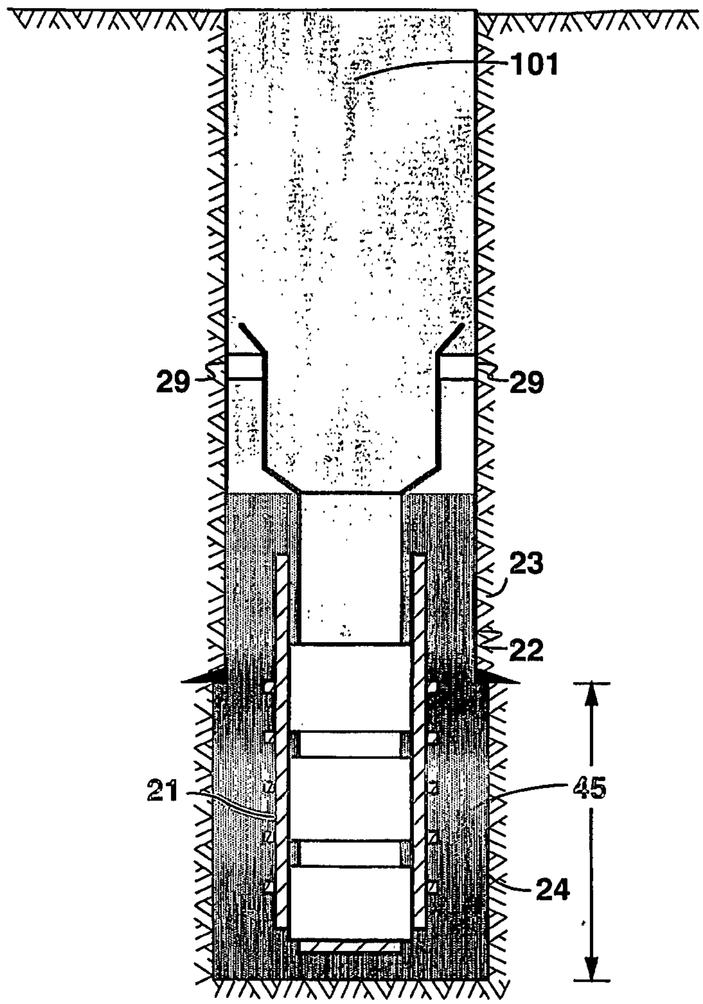

FIG. 11